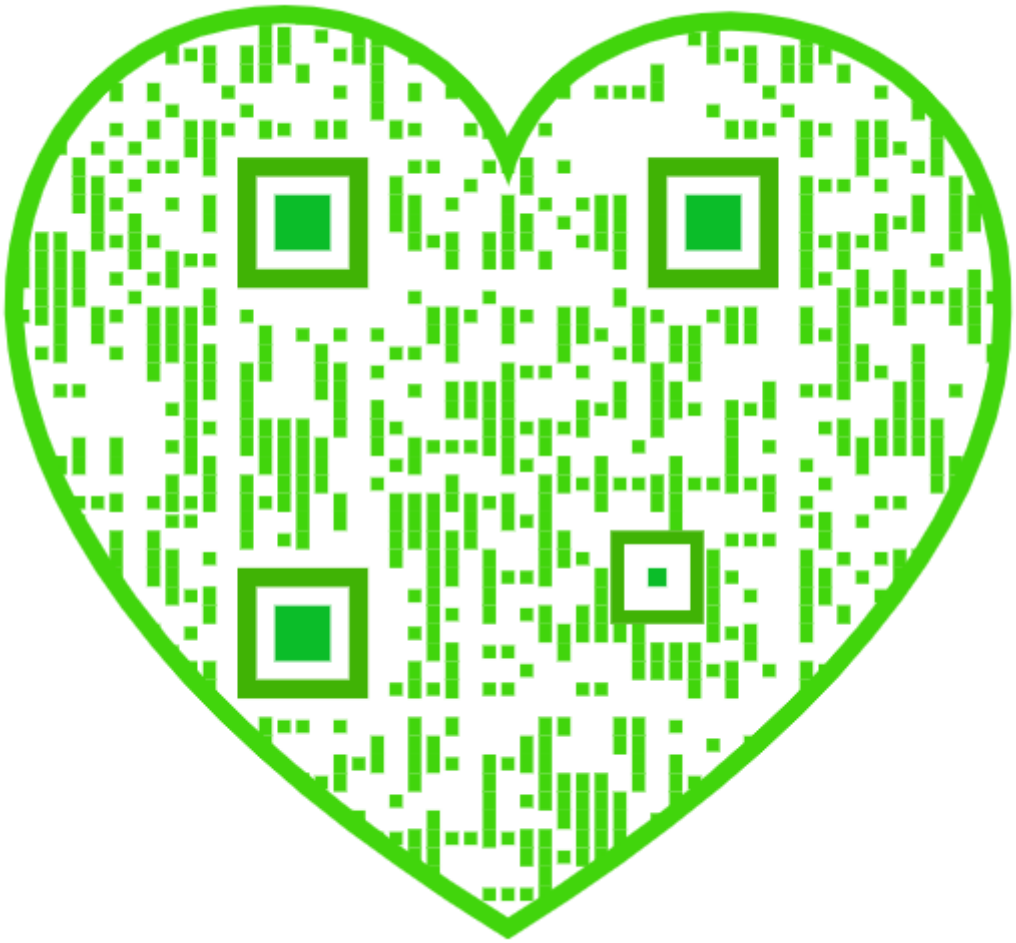

University of Maine

Maine Agricultural Experiment Station

ORONO

BULLETIN No. 174. DECEMBER, 1909.

BLACKLEG
A BACTERIAL DISEASE OF THE IRISH POTATO.

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BULLETIN No. 174.

BLACKLEG.

A Bacterial Disease of the Stem and Tuber of the Irish Potato.*

W. J. Morse.

For the past three seasons the writer has had under observation a stem and tuber disease of the Irish potato in Maine which in some respects presents rather grave aspects unless the growers and shippers of seed potatoes, in that part of the country where the disease has become established, take immediate and radical measures to prevent its propogation and spread. In this connection it should be mentioned that it is only here and there that the disease has as yet, assumed such proportions as to produce appreciable loss in this territory, and then more frequently in wet seasons or on low ground, but careful examination of fields over a considerable portion of the potato growing area of the state shows that this is a malady of much more general distribution than was first supposed.

Unfortunately, there is considerable reason to believe that the disease is conveyed to the new crop by means of infected seed tubers. While the majority of Maine's 18 to 20 million bushels of potatoes are sold for table stock the seed trade with southern states has, in the past few years, reached such proportions that it cannot be ignored. So far as can be learned, blackleg assumes much more serious aspect in the states farther south, and this

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* Attention has been called to this disease in the following previous publications of this Station. Bul. 149, p. 323 (1907) and Bul. 164, p. 2 (1909). It was briefly described on page 6 of a revised edition of a circular entitled "How to Fight Potato Enemies" (March 1908) and in September 1908 a newspaper bulletin was issued which briefly described the appearance, nature and cause of the disease and cautioned dealers against shipping seed tubers from fields affected with this trouble.

trade is demanding seed not only pure and true to name but also free from disease.

The fact that most of the outbreaks occurred many miles from the laboratory presented certain difficulties such that the organisms associated with the disease were not isolated in pure culture till late in the summer of 1908 when the disease was definitely proven to be of a bacterial nature. The study of these organisms is not completed, but certain facts of practical importance to the seed grower have been ascertained. Therefore it seems best to issue at this time a preliminary bulletin upon the more practical phases of the subject as now known and leave the more technical studies and final conclusions for a later publication.

Blackleg in America as is shown later, is a disease of more than local distribution, doubtless occurring to some extent at least over a considerable area of the potato growing sections in Eastern United States and Canada. There is reason to believe that it has existed in some localities for many years but it is only very recently that it has been recognized and recorded in the literature of American plant diseases. So far as the writer has been able to determine the first mention of this trouble in this country as a distinct disease was when Jones recorded its occurrence in Vermont in 1906,* and described in some detail the signs of the disease as it occurs in the field. Since its appearance in every way agreed with the *Schwarzbeinigkeit* or "blackleg" which he had studied in Europe † he used the same term as a common name of the American form of the disease. The writer was fortunate enough to see the field upon which Doctor Jones based his description. Since the appearance of the diseased plants as observed in Maine was identical with those seen in Vermont and since the term "blackleg" is especially applicable, suggesting the inky-black of the diseased stems it seems best to continue the use of this term.

Causal Organisms.

In July 1906 Harrison began the publication of a series of articles upon "A Bacterial Rot of the Potato, Caused by *Bacillus*

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* Jones, L. R., Vt. Sta. Rept. 19, p. 257 (1906).

† U. S. Dept. Agr., Bu. Pl. Ind. Bul. 87, p. 17 (1905).

*solanisaprus."** In this account he describes a disease of the stem and tuber of the Irish potato which he had under observation in different provinces of Canada at least as early as 1900. He very carefully studied and described in considerable detail the organism responsible for the disease, which he called *Bacillus solanisaprus,* n. sp., differing in some respects from the description of *B. solanicola* Delacroix and *B. phytophthorus,* the latter of which is given by Dr. Appel as the cause of the *Schwartzbeinigkeit* in Germany.† Professor Harrison found his organism to be pathogenic on various varieties of potatoes, and also demonstrated its ability to produce soft-rots on a considerable number of unrelated vegetables.

It is not the province of this article to discuss the relationship of the bacteria associated with blackleg in Maine with those already described as a cause of disease of the potato in America and elsewhere, or to take up in detail the morphological, cultural, physical and biochemical features of the organisms. When the studies now in progress are completed these questions will be discussed in detail but a general statement at this time may be of service.

Pathogens from two different sources have been secured which are not identical in all respects in cultural characters, but it is doubtful if these differences are of sufficient amount to constitute separate species. One of these agrees in most respects, as far as studied, with the published description of *B. solanisaprus,* except in its ability to ferment certain carbohydrates which Harrison says the latter does not ferment. Ordinarily this would be considered sufficient to constitute a separate species. On the other hand, extended study of the fermentation of dextrose, lactose, and saccharose by the closely related organisms causing soft-rots of various vegetables indicates that with germs of this class fermentation of the carbohydrates mentioned is not strong and is very variable. Hence with this group it is a questionable character upon which to erect a species.‡ More-

* Harrison, F. C., Central. f. Bakt. II Abt. XVII, p. 34 *et seq* (1906).

† Appel, Dr. Otto, Arb. K. Gsndhtsamt., Biol. Abt., 3 (1903), No. 4, pp. 364-432.

‡ Harding, H. A. and Morse, W. J. The Bacterial Soft Rots of Certain Vegetables. Technical Bulletin No. 11, Part 1. N. Y. Expt. Station (1909).

over preliminary work upon fermentation with an authentic culture of *B. solanisaprus* in comparison with the organisms isolated in Maine suggest the possibility that the differences in fermentative ability are not so great as was first supposed.

The blackleg organisms differ in cultural characters and in their effects upon the host from *Bacillus solanacearum* Smith, the cause of the Southern bacterial disease of the potato and egg-plant.

Character and Appearance of the Disease.

Plants affected by blackleg are readily distinguished in the field by any close observer, even at a distance. However, at first sight the general aspect of the diseased plants does not differ materially from that produced from several other causes which injure or kill the parts below or at the surface of the ground, such as the *Fusarium* disease, the *Rhizoctonia* trouble, or even mechanical injury to the stem. The affected plants appear more or less unthrifty and usually under sized, varying with the severity of the attack. The branches and leaves, instead of spreading out normally, tend to grow upward, forming a somewhat more compact top, frequently with the young leaves curled and folded up along the mid-rib. Later they become lighter green or even yellow and the whole plant gradually dies. If the disease progresses rapidly, the stem may fall over quite suddenly and wilt with very little previous signs of disease, other than the upward tend of the foliage noted above.

The diagnosis of suspected cases is easily confirmed by pulling up the affected plants. Blackleg as its name indicates, is characterized by a pronounced blackening of the stem below ground, usually running up one, two, or even three inches above the surface. Sometimes under very favorable conditions, i. e. continued wet, cloudy weather, especially where plants are growing on a naturally moist soil, the inky-black discoloration may follow up a portion of the stem for several inches above the ground.* During the active progress of the disease the invaded

* Inoculation of leaf petioles, or any part of a potato stem above or below ground with cultures of the bacteria isolated from diseased stems invariably produced the same characteristic black lesions. One plant was found in the field, however, which was affected with a rapid soft

tissues show a soft, wet decay. Preparations made from the tissues that are just being invaded, and examined with sufficient magnification show them to be filled with motile bacteria.

Ususally the seed tubers attached to affected stems are entirely decayed by a soft rot, or have disappeared entirely, while those attached to surrounding healthy plants are generally quite firm. If young tubers have been formed before the complete invasion of the stem they are occasionally affected in the same manner, although, as a rule, there is a tendency for the disease not to follows out upon the branches which bear the tubers but upward on the main stem toward the surface. Apparently the disease works more rapidly or attacks the plants as a rule at an earlier stage in their growth than the *Rhizoctonia* or "potato rosette" disease described by Rolfs in Colorado and Selby in Ohio,* for there is less tendency to produce little potatoes as there described. Occasionally when the disease makes slow progress on account of dry weather this tendency to throw out new shoots above the affected region bearing many small potatoes has been observed, even to the extent of producing small green tubers upon the stem above ground.

Out of a large number of affected fields examined only one indicated possible spreading in the field. This was in 1907. There was very little blackleg in the entire field of 20 acres except in one spot a few rods square where all the plants were diseased. It was first noticed near the center and gradually worked outward. The season was excessively wet, and the affected area coincided with a low pocket or depression in the field where water would stand for a few hours after each heavy rainfall, thus indicating how, in this exceptional case, the disease spread from hill to hill. In all other cases observed affected plants were scattered promiscuously over the field, always

decay of the aerial portions of stem without discoloration. Several cultures were obtained from colonies on plates poured from this stem. In every case tried these have, when inoculated into plants in the greenhouse, produced not the colorless decay of the stem but the characteristic blackleg decay. It may be said, however, that the bacteriological studies upon this strain, so far as made, indicate greater variation from the published description of *B. solanisaprus* than others being studied.

* Rolfs, F. M., Col. Exp. Sta., Bul. 70 (1902) and Bul. 91 (1904).
Selby, A. D., Ohio Exp. Sta. Bul. 139 (1903).

more common and more severely attacked on the lower or more moist portions of the field. If one stalk from a given seed-piece was diseased any others coming from the same piece were invariably found to be affected to a greater or less degree also.

As a rule the plants first begin to show signs of disease when they are 6 to 8 inches high and growing rapidly, i. e., in northern Maine at or soon following the first of July. The progress of the disease is markedly influenced by weather conditions. Very moist, cloudy weather may tend to favor rapid progress, resulting in the early death of the young plants, so that only the dead stalks remain scattered among the healthy plants, within a month or six weeks, or even less time after its first appearance. A period of dry weather coming on after the disease is well started below ground may check its progress, but cause the death of the plant at an equally early period on account of its inability to withstand the lessened water supply. Again conditions between these extremes, such as existed during the summer of 1909, may prolong the attack well into August.

In brief there is no evidence that blackleg under ordinary field conditions in Maine spreads from plant to plant in the field. The number of diseased plants appears to be determined by the number of infected seed-pieces planted, modified by conditions of the soil wet or dry. Infection of the growing plant always, so far as observed, begins below ground, usually at the junction of the stem with the seed piece, which probably decays or begins to decay before the stem is attacked. The rapidity of the progress of the disease and its severity varies with the weather conditions, or amount of moisture in the soil, but a plant once attacked never recovers sufficiently to produce merchantable tubers.

Means of Distribution.

As suggested in the preceding paragraph there is every reason to believe that blackleg is largely, if not wholly, distributed by means of infected seed tubers. As yet this statement is not backed up by sufficient experimental data, but observations so far made all point to this conclusion. Some of these observations are as follows:—

The first case in Maine seen by the writer was on new land recently cleared of forest and never before planted to any agri-

cultural crop. Here infection either came with the seed or existed on land never before under the plow, which latter seems improbable.

A field of four acres on the University Farm in 1907 was planted with seed from 5 or 6 different sources. Along one side 3 barrels of selected potatoes, Green Mountain variety each from a different source were planted. The plants from one of these barrel lots showed quite a percentage of blackleg but careful search, several times on different dates, over the remainder of the field failed to reveal a single diseased plant. The disease had not been previously seen on this farm. Case after case has been seen on different farms where one field or part of a field developed the disease while another field on the same farm or a part of the same field did not show it. Inquiry has invariably resulted in showing that the seed tubers from the two different areas came from different sources. Several attempts have been made to trace the seed to see if the disease was present on the farm where its was produced. A few cases presented data of some reliability, giving an affirmative answer to the question. The too common practice of growers selling their entire crop in the fall or winter and then picking up seed from mixed lots of local dealers, makes it impossible in most cases to trace the source of the seed.

In describing the outbreak on the Station farm in Vermont, Jones makes the following significant statement:—"The field was planted with Green Mountain potatoes, the seed being from Houlton, Maine."* This statement is all the more significant in view of the fact that as a specialist in the study of potato diseases he has conducted experimental work on this farm for twenty years, has had an intimate knowledge of the condition of every crop of potatoes raised thereon during this time, and this was the first recorded outbreak of blackleg.

Professor T. C. Johnson of the Virginia Truck Experiment Station says:** "I examined a field in Augusta County, (Virginia) in which some Maine grown Cobbler seed was planted, and also some home grown seed of other varieties. In portions of the Cobbler field the injury from 'blackleg' was as much as

* l. c., p. 258.

** In correspondence, September 1909.

8 to 10 per cent. The average injury from the field possibly not being over 3-5 per cent. The portions of the field planted to other varieties of home grown seed had no 'blackleg' whatever. I have not been able to find any 'blackleg' in the trucking fields in which home grown seed was used. The general opinion is that the disease was introduced with the seed potatoes but this has not been definitely proven."

Professor J. B. S. Norton writes, in answer to an inquiry, that during the past season he has seen one case of blackleg on a field planted to Maine seed in Somerset County, Maryland.

A letter from Professor G. E. Adams of Kingston, Rhode Island, states that in 1907 he found 5 hills of potatoes which appeared to be suffering from blackleg. "These potatoes were grown from seed which was obtained from England in the spring of that year." This is interesting as suggesting the possible origin of the disease in Maine. Harrison's account of the distribution and amount of damage produced by this disease in Canada,* even though we disregard the large amount of bacterial soft rot of the tuber following invasions of the late blight fungus *Phytophthora infestans* and the ordinary decay caused by this fungus itself, which he has apparently attributed to the soft rot associated with the stem-disease, indicates that blackleg is a more common and destructive disease in certain provinces of Canada than in any section of the United States thus far reported. Importation of seed stock from England would naturally be more common in Canada than to the United States. Therefore, it is conceivable that tubers infected with this disease have from time to time and at various places been introduced into Canada from England. Once in Canada, particularly in New Brunswick, the spread of the disease to Maine was a comparatively easy matter and a logical sequence, for Maine's greatest potato district borders on this latter province and quite a percentage of the potato growers of this section are former residents of the adjoining sections of Canada.

There is evidence that the introduction of the disease into some parts of Maine, at least, is by no means a matter of recent date. Many practical men when the diseased

* l. c., pp. 34 and 391.

plants are pointed out to them will say that they have seen occasional hills showing this trouble several years past, but have looked upon it as something of minor importance. Usually the period given varies from 5 to 10 years, but Mr. Borden Blackstone of Perham assures the writer that 30 years ago he observed something which he believes to be identical with this.

Partly Decayed Seed Tubers Spread the Disease.

In an attempt to artificially inoculate seed tubers in the spring of 1909 three bushels of tubers, Green Mountain variety, were used. One bushel was planted as purchased. The tubers of the other two bushels were liberally sprayed with a living, virulent culture of the bacteria which cause the disease. They were allowed to dry off while spread on the floor under an open shed away from direct sunlight, and covered lightly with builder's paper. Then one bushel of these latter was soaked in formaldehyde solution as is customary in treating for scab.* About a week later all three lots were planted. There was a good stand on all three plots, and no blackleg was observed on any of them. This was somewhat surprising in view of the experience of the previous year which was as follows:—Attempts to isolate the specific organisms from plants growing at a distance of from 50 to 100 miles from the laboratory, generally with the disease in the later stages when found, only resulted in failure during 1907, and the early part of the summer of 1908. Then recourse was had to the following method. Seed tubers bearing short sprouts were planted in boxes on July 25. Before planting the tubers were wet with a watery extract made by crushing some diseased stems, and, after planting, this extract was poured over the soil above. On August 18 several of the young stems from these tubers showed well developed cases of blackleg. From these virulent organisms were isolated with ease. In this connection it should be said that the tubers in the boxes were kept constantly quite wet while the land on which the culture-sprayed tubers were planted in 1909 was exceedingly dry for some weeks following. Later experiments showed that the

* Soaked 2 hours in a solution consisting of 8 fluid ounces of formalin (40% solution) formaldehyde and 15 gallons of water.

organism themselves were readily killed by drying. They were doubtless all dead before the tubers were planted.

The writer is of the opinion that the disease starts as a rule, not from organisms resting on the unbroken skin of the surface of the tuber, but rather from those lurking in wounds, cracks or decayed portions of the flesh of the tuber where the disinfecting solutions may not penetrate. Hence seed treatment with any disinfecting solution should be supplemented by rigid inspection and the rejection of seed tubers which show any diseased or unsound portions.

Geographical Distribution in America.

The extent of the distribution of this disease in the United States is indicated by the records of the Plant Disease Survey of the Bureau of Plant Industry at Washington. Mr. W. W. Gilbert, assistant pathologist, writes as follows: "I have looked through our records and find we have located the blackleg disease of potatoes in the following places: In South Carolina, in the trucking sections in the vicinity of Charleston; in Virginia, about Norfolk, Portsmouth, and at several points on the Eastern Shore; in Maryland at Beltsville; in New York, on Long Island; in Colorado in the vicinity of Greeley; in Ohio at Plainsville, and I find also a note of Mr. Orton's which states that the disease probably occurs in Oregon."

Answers to inquiries addressed to officials in experiment stations in the following states: Alabama, Connecticut, Delaware, Florida, Georgia, Kentucky, Maryland, New Hampshire, New Jersey, New York, North Carolina, Rhode Island, South Carolina, Vermont, Virginia and Wisconsin, indicates that except in Virginia the disease is not common enough to attract attention, it only being reported from the states mentioned below: From Connecticut Dr. Geo. P. Clinton writes: "I think that 'blackleg' disease you describe is the same as that I mention in my 1904 Report, p. 324, questioning if it is the southern bacterial disease." In Maryland Prof. J. B. S. Norton reports one authentic case from Somerset County, but expresses the opinion that the disease is more common than this indicates. One doubtful case is reported by Dr. F. L. Stevens of North Carolina. In Rhode Island Prof. G. E. Adams reports one case where the seed

tubers were imported from England. In Vermont Prof. H. A. Edson states that it has only been observed on one farm where it was first introduced with the seed and reported by Doctor Jones in 1906.* In Virginia Prof. T. C. Johnson first reported the existence of the disease to the writer some over a year ago, and writing on September 27, 1909, he says: "The 'blackleg' is becoming somewhat general in this section of Virginia." There can be no doubt as to the identity of the disease in Virginia and Maine as Professor Johnson is perfectly familiar with its appearance as it occurs in the field in both states.

In Maine, as has already been stated, the disease is not uncommon, but as a rule it occurs only as an occasional, isolated affected stalk scattered over the fields, though several cases were found during the two wet seasons of 1907 and 1909 where from 5 to 15 or 20 percent. of the plants were affected. These latter instances represented, with one exception, small fields of from one to 5 acres.

The similar appearing trouble which Harrison has described in Canada he stated had been found throughout the Province of Ontario, its presence had been reported from Nova Scotia, New Brunswick and Quebec, and one case reported from the North West Territory.†

Economic Aspects.

There is little evidence to show that blackleg has caused or is likely to cause serious and widespread losses on Maine potato fields although its occurence appears to be on the increase. While one of the worst cases found in 1909 was on well-drained, elevated land, the soil was quite wet on account of excessive rainfall throughout the season. So far as observed it is only to be feared as a serious pest in this section upon low, wet lands or on higher ground during abnormally wet seasons. However, in localities where the disease is prevalent during wet seasons, occasional affected hills are found upon the dryer soils and during years when the rainfall is not excessive.

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* See p. 310.

† l. c. p. 35.

In Virginia so far as can be learned from correspondence, etc., the disease appears to assume more serious proportions wherever it occurs at all, and there seems to be a growing conviction around Norfolk, and in some places on the Eastern Shore that it comes from and first occurs upon fields planted with northern seed.

Inoculation into sound tubers with pure cultures of the organisms associated with the disease produces a rapid soft-rot, and no doubt some of the loss from wet rot in the field and in storage is caused by this organism. However, in the writer's experience this is largely confined to the small tubers which have been formed in the hills attacked, before the stalks are killed. Even here only a small part of such tubers are found to be decayed. The disease appears to start from the seed piece, which is invariably decayed, and passes directly up the main stem. The under-ground, tuber-bearing branches of the stem are cut off and the disease follows them out a short distance, but more frequently it stops before reaching the young tubers. If the young tubers are reached a soft, wet decay results. Out of a large number of plants grown in pots and inoculated with pure cultures of the organisms, at or near the surface of the soil, in only a very few cases did the disease spread downward and outward on the underground branches of the stem sufficiently as to reach and cause decay of the young tubers.

The fact that the organism so readily and rapidly destroys potato tubers when inoculated into them would indicate that in addition to producing a dangerous stem-disease it has potential qualities for becoming a serious pest as a cause of tuber decay. However, there is no evidence that this has been the case in Maine in the past. Epidemics of potato-rot are not infrequent, but these are invariably associated with and follow outbreaks of late blight, *Phytophthora infestans* De Bary, upon the foliage and this fungus is invariably found in the decayed tubers. Even in seasons when the late blight is rife the rot is almost entirely controlled by proper and thorough spraying of the foliage which would not be the case if the blackleg organism was a contributing factor.

In these epidemics of tuber decay following late blight while the rot as a rule shows the characteristics of that caused by the late blight fungus, there is associated with it very frequently

a soft, foul-smelling decay which is apparently of a bacterial nature. While there is every reason to believe that the blackleg organism is capable of causing some of this soft bacterial decay the writer's experience leads him to believe the great majority of it is caused by secondary infection by saprophytic bacteria following the invasion and killing of the healthy tissues by the late blight fungus. Attempts to isolate bacteria capable of destroying healthy tubers from those so diseased have invariably resulted in failure. The removal of some of the soft, decayed tissue from such tubers and inserting it in sound tubers led to no decay of the latter, while the same procedure where the decayed tissue was taken from a rotting tuber previously inoculated with the blackleg organism invariably produced a characteristic and rapid decay of the healthy tuber into which it was inserted.

Moreover, this soft-rot of the tuber following and associated with the decay caused by *Phytophthora infestans* is familiar to all who have had much practical, field experience with outbreaks of disease caused by this fungus, and has been observed frequently by horticulturists and plant pathologists in this country upon fields which showed no evidence of blackleg upon the growing stems. If the organism was present in sufficient degree to cause material loss from tuber decay it would seem that its appearance on the stem could not have escaped notice.

Harrison* apparently takes an opposite view to the above and seems inclined to attribute to his *B. solanisaprus* a much more active part in the cause of tuber decay in Canada. He asserts that the Experimentalist of the Ontario Agricultural College and others have confused the terms "blight" and "rot", but fails to state distinctly that *Phytophthora infestans* not only causes the well known blight of the foilage but also is a well recognized cause of decay of the tuber often referred to as the "late blight rot." He shows, in one instance, at least, where spraying for fungi was practiced, that the real cause of the rot was of a bacterial nature. However, the statements to which he objects such as "The potatoes grown in the Experimental Department have been comparatively free from blight, although

* l. c. pp. 34 and 391.

in some parts of the Province the rot has proven very troublesome in some seasons" and "results show that there was less rot on the potatoes on which Bordeaux mixture and Paris Green were used" are not necessarily confusing. They might be made with propriety in referring to the late blight of the foliage and the infection and decay of the tuber by the same fungus resulting from spores being washed down into the soil from the diseased leaves, and in no way be confused with the bacterial trouble.

To summarize, in no part of the United States has blackleg as yet produced widespread and severe losses to the potato crop. Such losses as have been experienced in Maine are largely confined to the killing of the affected plants before the tubers have reached merchantable size but the amount of this loss appears to be increasing. Little or no loss from decay of mature tubers by this disease has been observed in this state, but much loss from tuber decay in Canada is credited to *B. solanisaprus*. However, the distribution of the disease is becoming quite general, and it may become a serious pest under certain favorable conditions and in certain sections of the country. In Maine while the losses from diminished crops have not been and may not be great, the real danger is from the possible loss of a valuable seed trade from certain sections where the disease may assume more serious proportions than it does in this state.

Means of Prevention.

The observations here recorded and the uncompleted bacteriological studies of the organisms associated with the disease indicate that the introduction of blackleg into uninfected soils can easily be prevented. The organisms are readily killed by exposure to sunlight, even in December when the intensity of the sun's rays is at its lowest ebb. They are also quite susceptible to dessication. Young, active, vigorous cultures spread upon small sterile, glass discs, allowed to dry at room temperature were found to be dead in less than half an hour after the moisture had disappeared from the surface of the smear, and thus far no evidence of spore formation has been observed in old cultures. They are, however, able to live a long time in the presence of moisture.

The introduction of small quantities of living, beef-broth cultures into tubes of sterile water containing formaldehyde or corrosive sublimate killed the germs, although the percentage of the two germicides used was many times less than that of the disinfection solution later recommended, and the exposure being for a much shorter period. The germs introduced into control tubes of pure sterile, distilled water at the same time were not killed.

The fact that the organisms are readily killed by drying and, as already stated, (p. 317), no disease was produced by spraying smooth seed tubers with vigorous active culture and allowing them to dry several days before planting indicates that the germs are probably not carried over on the surface of the tubers. Very likely they live over winter in wounds or cracks in the seed tubers or in small decayed areas, there being sufficient moisture to keep them alive but the temperature of storage is low enough to arrest their active development till after the tubers are planted and begin to put forth shoots.

Hence as a means of prevention: First, select seed, if possible, from fields upon which the disease has not appeared. Second, discard for seed purposes all tubers which have wounds, cracks or decayed areas*. Third, disinfect all seed tubers with corrosive sublimate or formaldehyde before cutting. Spreading the seed tubers out in thin layers in a clean, dry place exposed to the direct rays of the sun for several days would be an excellent supplementary practice and tend to hasten germination as well. The disinfection of seed tubers and the rejection of all such as show blemishes or diseased areas will not only prevent the spread of blackleg but also the propogation and spread of scab and most other tuber diseases which attack the potato in Maine.

Methods of Disinfecting Seed Potatoes.

For disinfecting seed tubers for blackleg the same methods are recommended as for potato scab. Either of the following may be used.

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* This sorting out of the diseased tubers should always be done as far as possible before cutting on account of possible contamination of the freshly cut, moist surfaces of healthy seed pieces by germs carried by the hands or knives used in cutting those tubers where the diseased areas extended below where the disinfecting agents penetrated.

Liquid Disinfection.

No. 1.

Corrosive sublimate	2 ounces
Water	15 gallons.

Immerse seed tubers for 1½ hours in this solution.

No. 2.

Formaldehyde (40% solution) 8 fluid ounces	(½ pint).
Water	15 gallons.

Immerse seed tubers 2 hours in this solution.

Corrosive sublimate dissolves readily in water, but wooden containers must be used on account of its corrosive action upon metals. On account of its poisonous nature the corrosive sublimate solution must be kept out of reach of animals which might drink it, and the treated tubers should not be used for food. There is no danger from the use of formaldehyde, it is non-poisonous to the higher forms of animal life as ordinarily used. Since both of these solutions are effective No. 2 is recommended in preference wherever formaldehyde can be purchased, for the reasons given above.

While no experiments have been tried upon the blackleg organisms to determine the germicidal effect of formaldehyde gas generated by means of potassium permanganate its successful use in destroying the bacteria associated with certain contagious diseases of man is well known. The writer has also found this method equally, if not more effective, in treating seed tubers for potato scab than soaking in the solutions already mentioned. Therefore, if a large amount of seed tubers is to be treated at one time the following gas treatment is recommended.

Disinfection with Formaldehyde Gas.

Potassium permanganate	23 ounces
Formaldehyde (40% solution)	3 pints

The above is sufficient for each 1000 cubic feet of space.

The disinfection with formaldehyde gas should be done before the sprouts begin to start on the seed tubers. Place the seed tubers in bushel crates or shallow slat-work bins in a room where all cracks have been tightly stopped and the door made

as near air-tight as possible, when closed. Spread the potassium permanganate evenly over the bottom of a large, rather deep pan or pail. If the quantity is large a small wash tub, or half of a barrel may be used. Pour in the formaldehyde and give the dish one rapid tilt to ensure thorough mixing; leave the room at once and tightly close from without. Keep closed for about 24 hours, or at least over night.

The dish used for a generator should be placed in the middle of the room. *To avoid injury from the strong gas as it is liberated no potatoes should be placed directly above the generator.* It is also better to leave a clear space of at least three feet on all sides of the generator, and the slat-work bins or crates should be so arranged that the gas can circulate on all sides of them and mix with the air of the room before it comes in contant with the potatoes. Formaldehyde gas possesses about the same specific gravity as air, but when generated in this way the strong gas is driven off very rapidly mixed with hot, watery vapor and probably the most of it goes first to the top of the room, but it quickly diffuses and mixes with the air contained therein.

Temperature is an important factor in disinfecting with formaldehyde. It is more effective above 80 degrees F. and disinfection with this gas should never be attempted where the temperature of the chamber used is below 50 degrees F. A certain amount of moisture in the air is also very essential, therefore just before placing the formaldehyde in the generator the floor of the disinfecting chamber should be thoroughly wet down with boiling water. However, no water should be placed on the tubers to be treated.

The exposure of the tubers to the gas should not be made in sacks. It takes a large volume of gas and a long exposure to penetrate the sacks. Large quantites of the formaldehyde are lost by uniting chemically with the organic matter of the fabric, and the meshes tend to convert the gas into a solid substance known as paraform.

Upon completion of the time required to disinfect, the door of the room is opened and in a very short time the gas will have diffused outward sufficiently to allow the treated tubers to be taken out. There is absolutely no danger to human beings in working with the gas as here recommended. When first

going into the room it may cause some irretation of the mucous membranes of the nose and throat but this soon passes away.

It should be mentioned that the amounts of formaldehyde here recommended and the length of exposure to the gas are far in excess of that found necessary for disinfecting rooms for contagious diseases, and are doubtless considerably greater than are needed for treating seed tubers. However, experiments have shown that the large amount of gas and long exposure, if done according to directions here given, will not injure the germinating quality of the tubers and will control the scab fungus as well, therefore, it seems best to advise a treatment which will answer for both diseases at the same time. If it is desired to reduce the amount of solution and the time of exposure the writer would not advise going below 2 pints of formaldehyde solution and a proportionate amount of potassium permanganate for each 1000 cubic feet of space and 12 hours for the lower limit of exposure.

Whether or not the disease germs can remain in the soil for any length of time to infect later crops is still an open question. The fact that field observations show that the disease, as has already been stated, is almost invariably confined to scattered hills and to stalks which spring from decayed seed pieces indicates that most or if not all the infection comes from diseased seed. However, the somewhat closely related organisms which are associated with the soft rots of cabbage, cauliflower, etc., apparently remain alive in the soil for some time at least. There is no reason why the blackleg organism should not do the same. Therefore, land upon which a potato crop has been grown which was attacked by this disease should be kept in other crops, preferably grass, clover or cereals, for as long as possible before again using it for potatoes. The practice of growing two crops of potatoes on the same land in successive years should be discouraged, and low, poorly drained soils should be avoided. Fields which show scattered affected stalks should be frequently inspected during the growing season and all diseased plants and any tubers which may have formed on them dug up and burned. Under no condition should the crop from badly or even moderately affected fields be used for planting in Maine or shipped South for seed. Several of the leading seed dealers in Maine are doing their best

to comply with these recommendations and all growers should cooperate with them in their efforts to furnish stock free from disease.

Summary.

Blackleg is a bacterial disease of the stem and tuber of the potato. A similar appearing malady caused by bacteria has been reported from Canada, and another from England, Germany, France and other parts of Europe. Preliminary studies of the organisms associated with the disease indicate that they are closely related to those already described as a cause of similar troubles elsewhere, but whether they are identical with any of the described species of bacteria is not fully determined. pp. 309-312.

The attacked plants are usually unthrifty, light green or even yellow, and undersized. The branches and leaves have a tendency to grow upward forming a rather compact top, often with the young leaves curled and folded up along the mid-rib. The most characteristic thing about them is the inky-black discoloration of the stem, at or below the surface of the ground, but frequently running up the stem from one to several inches above ground. The seed-piece from which the attacked plants spring is invariably attacked with a soft-rot, and the disease appears to start on the stem at its junction with the diseased seed tuber. The germs of the disease are capable of causing a rapid decay of the young tubers, and these are sometimes attacked also. pp. 312-314.

The evidence thus far obtained indicates that blackleg is largely distributed by means of germs carried in wounds, cracks and decayed areas of seed tubers. On account of the readiness with which the organisms are killed by drying there is little to fear from sound, smooth seed stock, but this should be treated with a disinfecting solution as a matter of precaution. There is some reason to think that blackleg was introduced into Canada from England and from there to the United States. pp. 314-318.

Blackleg is apparently becoming quite widely distributed throughout the Eastern part of the United States. In most states it is not common enough to attract attention, and in no region has it done much damage, although it may become a

serious pest in some sections. It is not believed that it is likely to do much damage in Maine, except in low, wet soils or during abnormally wet seasons. The similar appearing trouble caused by *Bacillus solanisaprus* Harrison is widely distributed in Canada and is there claimed to be of considerable economic importance as a cause of tuber decay. pp. 318-322.

The propogation and spread of the disease probably can be controlled largely by the selection of seed from fields free from the disease, the rejection of all seed tubers which have wounds, cracks or decayed areas and treating the remainder with corrosive sublimate or formaldehyde solutions, or with formaldehyde gas as is done for potato scab. It is not known whether or not the disease germs will remain alive in the soil to infect future crops of potatoes, but as a precautionary measure the land on which the disease occurs should be kept in grass, clover, or cereals for as long a time as possible before planting it to potatoes again. pp. 322-326.

MAINE SEED POTATOES.

This Station has recently published a circular entitled "Certain Diseases of Maine Potatoes and Their Relation to the Seed Trade." In this circular attention is called to the fact that owing to peculiar climatic conditions under which they are produced, Maine grown seed potatoes have been found to possess exceptional qualities for planting in the south. The large and rapidly increasing use of northern seed in the south has raised the issue of possible disease transference by this means.

In the circular in question the fact is pointed out that as a rule Maine seed potatoes are as free from disease as any produced in other northern states with like climatic conditions. Certain potato diseases which may be conveyed by seed tubers are described and the means by which they may be avoided or controlled are given in detail. Copies of this circular will be mailed to any address on request.

Requests for publications should be addressed to the

MAINE AGRICULTURAL EXPERIMENT STATION,
Orono, Maine.